EXHIBIT 3

NFPA®

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Guide for Fire and Explosion Investigations

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Fire and Explosion Investigations

2024 Edition

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Chapter 1 Administration

1.1 Scope. This document is designed to assist individuals who are charged with the responsibility of investigating and analyzing fire and explosion incidents and rendering opinions as to the origin, cause, fire spread, responsibility, or prevention of such incidents and the damage and injuries that arise from such incidents.

1.1.1 The completion of reports for the United States National Fire Incident Reporting System (NFIRS) are outside the scope of this guide.

1.1.2 This guide considers NFIRS reports as incident reports and not as investigation reports. The information contained in an NFIRS report should generally be considered as the preliminary report of the fire department concerning any fire or explosion incident. An NFIRS report should not be used as a fire investigation report.

Δ 1.2 Purpose.

1.2.1 The purpose of this document is to establish guidelines and recommendations for the safe and systematic investigation or analysis of fire and explosion incidents. Fire investigation or analysis and the accurate listing of causes are fundamental to the protection of lives and property from the threat of hostile fire or explosions. It is through an efficient and accurate determination of the cause and responsibility that future fire incidents can be avoided. This document has been developed as a model for the advancement and practice of fire and explosion investigation, fire science, technology, and methodology.

1.2.2 Proper determination of fire origin and cause, as well as the cause of and responsibility for property damage, injuries, or deaths, is also essential for the meaningful compilation of fire statistics. Accurate statistics form part of the basis of fire prevention codes, standards, and training.

1.3 Application. This document is designed to produce a systematic, working framework or outline by which effective fire and explosion investigation and origin and cause analysis can be accomplished. It contains specific procedures to assist in the investigation of fires and explosions. These procedures represent the judgment developed from the NFPA consensus process system that if followed can improve the probability of reaching sound conclusions. Deviations from these procedures, however, are not necessarily wrong or inferior but need to be justified.

1.3.1 The reader should note that frequently the phrase *fire investigation* is used in this document when the context indicates that the relevant text refers to the investigation of both fires and explosions.

1.3.2 As every fire and explosion incident is in some way unique and different from any other, this document is not designed to encompass all the necessary components of a complete investigation or analysis of any one case. The scientific method, however, should be applied in every instance.

1.3.3 Not every portion of this document may be applicable to every fire or explosion incident. It is up to investigators (depending on their responsibility, as well as the purpose and scope of their investigation) to apply the appropriate recommended procedures in this guide to a particular incident.

1.3.4 In addition, it is recognized that the extent of the fire investigator's assignment, time and resource limitations, or existing policies may limit the degree to which the recommendations or techniques in this document will be applied in a given investigation.

1.3.5 This document is not intended as a comprehensive scientific or engineering text. Although many scientific and engineering concepts are presented within the text, the user is cautioned that additional scientific or technical resources, training, and education may often need to be utilized in an investigation.

1.4 Units of Measure. Metric units of measurement in this guide are in accordance with the modernized metric system known as the International System of Units (SI). The unit of liter is outside of but recognized by SI and is commonly used in international fire protection. These units are listed in Table 1.4.

FIGURE 6.5.10.2 Flash Fire Damage on Plastic Wrapper and Paper Roll.

dynamics of the fire spread will be dictated by the compartment and fuel geometry and the relative heat release rates of these secondary fuels. The relatively short duration of the burning may have little impact on the flashover in the compartment as compared to the burning of the secondary fuels. Therefore, origin determination of such a flash fire can be supported by accurate witness observations and the analysis of the potential ignition sources in the areas where the vapor or gas could have existed. When the analysis of fire patterns is the only means of determining the origin, the investigator should be aware that the resultant ignition of secondary fuels and compartment flashover could have altered or obliterated the subtle patterns created by the flash fire.

6.5.10.2.2 Fuel Consumption. The difficulty in detecting patterns caused by flash fires is the result of the total consumption of available fuel without significantly raising the temperatures of other combustibles. In this case, the fire patterns may be superficial and difficult to trace to any specific point of ignition as in Figure 6.5.10.2.2. In addition, separate areas of burning from pocket fuel gas may exist and further confuse the tracing of fire spread.

6.5.10.2.3 Saddle Burns. Saddle burns are distinctive U- or saddle-shaped patterns that are sometimes found on the top edges of floor joists. They are caused by fire burning downward through the floor above the affected joist. Saddle burns display deep charring, and the fire patterns are highly localized and gently curved. They also may be created by radiant heat from a burning material in close proximity to the floor, including materials that may melt and burn on the floor (e.g., polyurethane foam). Ventilation caused by floor openings may also

FIGURE 6.5.10.2.2 Blistering of Varnish on Door and Slight Scorching of Draperies, the Only Indications of the Natural Gas Flash Fire.

FIGURE 6.5.10.2.3 Saddle Burn in a Floor Joist.

contribute to the development of these patterns, shown in Figure 6.5.10.2.3.

N **6.6 Fire Effects on Electrical Systems and Components.**

N **6.6.1 Electrical Faults.** An electrical fault will usually produce characteristic damage that may be recognized after a fire. Evidence of these faults may be useful in locating the area of origin. The damage may occur on conductors, contacts, terminals, conduits, or other components. However, many kinds of damage can occur from nonelectrical events. Section 6.6 will give guidelines for deciding whether observed damage was caused by electricity or fire attack. These guidelines are not absolute, and many times the physical evidence will be ambiguous and will not allow a definite conclusion. Conductors may be damaged before or during a fire by other than electrical means and often these effects are distinguishable from electrical activity.

N **6.6.1.1** As fire impinges on electrical wiring, the first change will be the degradation of the insulating materials. This degradation will depend on the duration of and exposure to the fire. If the exposure is sufficient, insulation breakdown can occur, potentially leading to an electrical fault. The insulation may be only damaged, or it can be completely consumed. However, it is

Chapter 18 Origin Determination

18.1 Introduction. This chapter recommends a methodology to follow in determining the origin of a fire. The origin of a fire is one of the most important hypotheses that an investigator develops and tests during the investigation. Generally, if the origin cannot be determined, the cause cannot be determined, and generally, if the correct origin is not identified, the subsequent cause determination will also be incorrect. The purpose of determining the origin of the fire is to identify in three dimensions the locations at which the fire began.

18.1.1 This chapter deals primarily with the determination of origin involving structures; however, the methodology generally applies to all origin determinations. Separate chapters address the particular requirements for determining origin in nonstructure fire incidents (motor vehicles, vessels, wildfire, etc.).

18.1.2 Determination of the origin of the fire involves the coordination of information derived from one or more of the following:

(1) *Witness Information and/or Electronic Data.* The analysis of observations reported by persons who witnessed the fire or were aware of conditions present at the time of the fire as well as the analysis of electronic data including but not limited to security camera footage, alarm system activation, or other such data recorded in and around the time of the fire event *(see Chapter 14)*

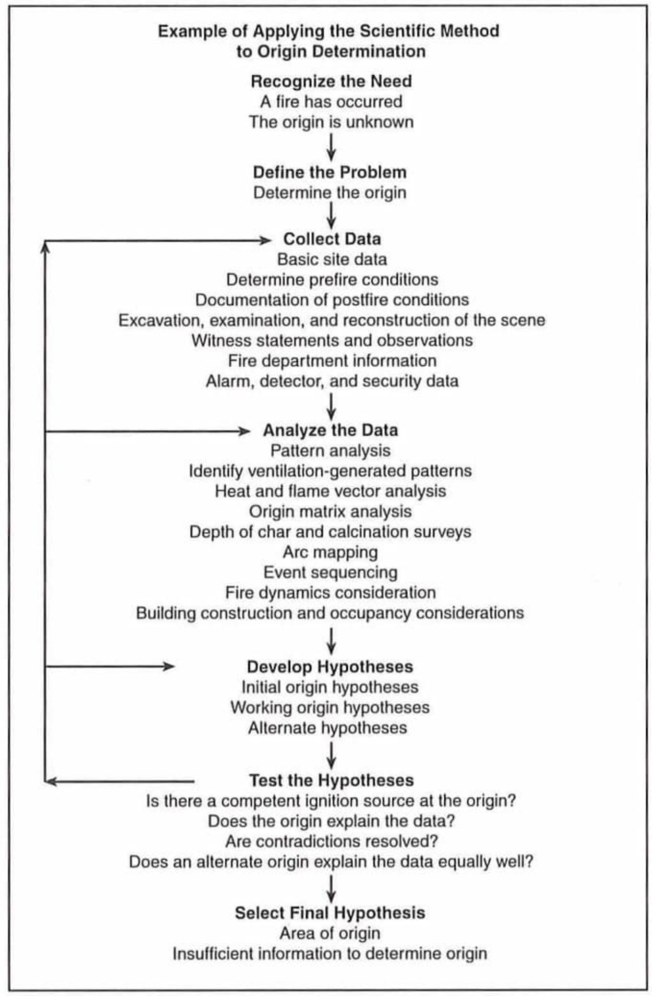
(2) *Fire Patterns.* The analysis of effects and patterns left by the fire, which may include patterns involving electrical conductors *(see Chapter 6)*

(3) *Fire Dynamics.* The analysis of the fire dynamics [i.e., the physics and chemistry of fire initiation and growth *(see Chapter 5)* and the interaction between the fire and the building's systems *(see Chapter 7)*]

18.2 Overall Methodology. The overall methodology for determining the origin of the fire is the scientific method as described in Chapter 4. This methodology includes recognizing and defining the problem to be solved, collecting data, analyzing the data, developing hypotheses, and most importantly, testing the hypothesis or hypotheses. In order to use the scientific method, the investigator must develop at least one hypothesis based on the data available at the time. These hypotheses should be considered "working hypotheses," which upon testing may be discarded, revised, or expanded in detail as new data is collected during the investigation and new analyses are applied. This process is repeated as new information becomes available. *(See Figure 18.2.)*

18.2.1 Testing any origin hypothesis requires an understanding of the associated fire events as well as the growth of the fire and how the fire spread through the structure. A narrow focus on only identifying the first item ignited and a competent ignition source fails to take into account important data that can be used to test any origin hypothesis. In such a narrow focus, the growth and spread of the fire and the resulting fire damage are not well considered.

18.2.1.1 The purpose of the fire spread analysis is to determine whether the resulting physical damage and available data are consistent with the area of origin hypothesis. For example, a fire starting in a wastebasket is a plausible working hypothesis, but the resulting fire damage would be highly dependent on the position of the first fuel and any subsequently ignited fuels. If the wastebasket had been located in an area with no adjacent fuel, then the results may be significantly different than if the wastebasket had been located next to a polyurethane sofa. Both hypotheses posit the same first item ignited, but the outcome is very different. Thus, if the origin hypothesis is not consistent with the resulting growth and spread of the fire, it is not a valid hypothesis. Fire spread scenarios within a compartment or building should be analyzed using the principles of fire dynamics presented in Chapter 5 and fire pattern development in Chapter 6.



Δ FIGURE 18.2 An Example of Applying the Scientific Method to Origin Determination.

18.2.1.2 In some instances, a single item, such as an irrefutable article of physical evidence or a credible eyewitness to the ignition, or a video recording, may be the basis for a determination of origin. In most cases, however, no single item is sufficient in itself. The investigator should use all available resources to develop origin and spread hypotheses and to determine which hypotheses fit all of the evidence available. When an apparently plausible hypothesis fails to fit some item of evidence, the investigator should try to reconcile the two and determine whether the hypothesis or the evidence is erroneous.

18.2.1.3 In some cases, it will be impossible to fix the point of origin of a fire. Where a single point cannot be identified, it

how the procedures set forth in this chapter follow the scientific method.

18.5.1 Initial Hypothesis. The initial origin hypothesis is developed by considering witness observations, by conducting an initial scene assessment, and by attempting to explain the fire's movement through the structure. This process is accomplished using the methods described in earlier sections of this chapter. The initial hypothesis allows the investigator to organize and plan the remainder of the origin investigation. The development of the initial hypothesis is a critical point in the investigation. It is important at this stage that the investigator attempt to identify other feasible origins, and to keep all reasonable origin hypotheses under consideration until sufficient evidence is developed to justify discarding them.

18.5.2 Modifying the Initial Hypothesis. The investigation should not be planned solely to prove the initial hypothesis. It is important to maintain an open mind. The investigative effort may cause the initial hypothesis to change many times before the investigation is complete. The investigator should continue to reevaluate potential areas of origin by considering the additional data accumulated as the investigation progresses.

18.6 Testing an Origin Hypothesis for Validity. In order to conform to the scientific method, once a hypothesis is developed, the investigator must test it using deductive reasoning. A test using deductive reasoning is based on the premise that *if* the hypothesis is true, *then* the fire scene should exhibit certain characteristics, assuming that the fire did not subsequently obliterate those characteristics. For example, if a witness stated that a specific door was closed during the fire, then there should be a protected area on the door jamb, which would tend to prove the hypothesis that the door was closed. *(See Chapter 4 and A.4.3.6.)*

18.6.1 Means of Hypothesis Testing. During the investigation, the investigator may develop and test many hypotheses about the progress of the fire. For example, the investigator often has to determine whether a door or window was open or closed. Ultimately, the origin determination is arrived at through the testing of origin hypotheses. A technically valid origin determination is one that is uniquely consistent with the available data. In testing the hypothesis, the questions addressed in 18.6.1.1 through 18.6.1.3 should be answered.

18.6.1.1 Is there a competent ignition source at the hypothetical origin? The lack of a competent ignition source at the hypothesized origin should make the hypothesis subject to increased scrutiny. Investigators should be wary of the trap of circular logic. While the cause of the fire was at one time necessarily located at the point of origin, the investigator who eliminates a potential ignition source because it is "not in the area of the hypothesized origin," needs to be especially diligent in testing the origin hypothesis and in considering alternate hypotheses. *(See Section 19.2.)* This is particularly true in cases of full room involvement. Unless there is reliable evidence to narrow the origin to a particular portion of the room, every potential ignition source in the compartment of origin should be given consideration as a possible cause.

18.6.1.2 Can a fire starting at the hypothetical origin result in the observed damage? The investigator should be cautious about deciding on an origin just because a readily ignitible fuel and potential ignition source are present. The sequence of events that bring the ignition source and the fuel together and cause the observed damage indicates the origin, and ultimately the cause. The hypothetical origin should not only account for physical damage to the structure and contents, but also for the exposure of occupants to the fire environment.

18.6.1.3 Is the growth and development of a fire starting at the hypothetical origin consistent with available data at a specific point(s) in time? Few data are more damaging to an origin hypothesis than a contradictory observation by a credible eyewitness. Any data can be contradictory to the ultimate hypothesis. The data must be taken as a whole in considering the hypothesis, with each piece of data being analyzed for its reliability and value. Ultimately, the investigator should be able to explain how the growth and development of a fire, starting at the hypothesized origin, is consistent with the data.

18.6.2 Analytical Techniques and Tools. Analysis techniques and tools are available to test origin hypotheses. Using such tools and techniques to analyze the dynamics of the fire can provide an understanding of the fire that can enhance the technical basis for origin determinations. Such analyses can also identify gaps or inconsistencies in the data. The utility of fire dynamics tools is not limited to hypothesis testing. They may also be used for data analysis and hypothesis development. Techniques and tools include time line analysis, fire dynamics analysis, and experimentation.

18.6.2.1 Time Line Analysis. Time lines are an investigative tool that can show relationships between events and conditions associated with the fire. These events and conditions are generally time-dependent, and thus, the sequence of events can be used for testing origin hypotheses. Relevant events and conditions include ignition of additional fuel packages, changes in ventilation, activation of heat and smoke detectors, flashover, window breakage, and fire spread to adjacent compartments. Much of this information will come from witnesses. Fire dynamics analytical tools *(see 21.4.8)* can be used to estimate time-dependent events and fire conditions. A more detailed discussion of time lines is included in Section 21.2.

18.6.2.2 Fire Modeling. Fundamentals of fire dynamics can be used to test hypotheses regarding fire origin. Such fundamentals are described in the available scientific literature and are incorporated into fire models ranging from simple algebraic equations to more complex computer fire models *(see 21.4.8)*. The models use incident-specific data to predict the fire environment given a proposed hypothesis. The results can be compared to physical and eyewitness evidence to test the origin hypothesis. Models can address issues related to fire development, spread, and occupant exposure.

18.6.2.3 Experimental Testing. Experimental testing can be conducted to test origin hypotheses. If the experimental testing results are substantially similar to the damage at the scene, the experimental data can be said to be consistent with the origin hypothesis. If the experimental testing produces results that are not substantially similar with the damage, an alternative origin hypothesis or additional data may need to be considered, taking into account potential differences between the experimental testing and the actual fire conditions. The following is an example of such an experiment. The hypothesized origin is a wicker basket located in the corner of a wood-paneled room. The data from the actual fire shows the partial remains of the wicker basket, undamaged carpet in the corner, and wood paneling still intact in the corner. A fire test replicating the hypothesized origin totally consumes the carpet, the wicker basket, and the wood paneling. Thus (assuming the test replicated the prefire conditions), testing revealed that this

(3) Ignition of secondary fuel items
(4) Thermal transmission through building elements

21.4.3 Flammable Gas Concentrations. Models can be used to calculate gas concentrations as a function of time and elevation in the space and can assist in identifying ignition sources. Flammable gas concentration modeling, combined with an evaluation of explosion or fire damage and the location of possible ignition sources, can be used (a) to establish whether or not a suspected or alleged leak could have been the cause of an explosion or fire, and (b) to determine what source(s) of gas or fuel vapor were consistent with the explosion or fire scenario, damage, and possible ignition sources.

21.4.4 Hydraulic Analysis.

21.4.4.1 Analysis of automatic sprinkler and water supply systems is often required in the evaluation of the cause of loss. The same mathematical models and computer codes used to design these systems can be used in loss analysis. However, the methods of application are different for design than they are for forensic analysis.

21.4.4.2 A common application of hydraulic analysis is to determine why a sprinkler system did not control a fire. Modeling can also be used to investigate the loss associated with a single sprinkler head opening, to investigate the effect of fouling in the piping, and to determine the effect of valve position on system performance at the time of loss. There are also models and methods available to analyze flow through systems other than water-based systems, such as carbon dioxide, gaseous suppression agents, dry chemicals, and fuels.

21.4.5 Thermodynamic Chemical Equilibrium Analysis. Fires and explosions believed to be caused by reactions of known or suspected chemical mixtures can be investigated by a thermodynamics analysis of the probable chemical mixtures and potential contaminants.

21.4.5.1 Thermodynamic chemical equilibrium analysis can be used to evaluate various hypotheses, including those relating to the following:

(1) Reaction(s) that could have caused the fire/explosion
(2) Improper mixture of chemicals
(3) Role of contamination
(4) Role of ambient conditions
(5) Potential of a chemical or chemical mixture to overheat
(6) Potential for a chemical or chemical mixture to produce flammable vapors or gases
(7) Role of human action on process failures

21.4.5.2 Thermodynamic reaction equilibrium analysis traditionally required tedious hand calculations. Currently available computer programs make this analysis much easier to perform. The computer programs typically require several material properties as inputs, including chemical formula, mass, density, entropy, and heat of formation.

21.4.5.3 Chemical reactions that are shown not to be favored by thermodynamics can be eliminated from consideration as the cause of a fire. Thermodynamically favored reactions must be further analyzed to determine whether the kinetic rate of the considered reactions is fast enough to have caused ignition, given the particular circumstances of the fire.

21.4.6 Structural Analysis. Structural analysis techniques can be utilized to determine reasons for structural failure or change during a fire or explosion. Numerous references can be found in engineering libraries, addressing matters such as strength of materials, formulas for simple structural elements, and structural analysis of assemblies.

21.4.7* Egress Analysis. The failure of occupants to escape may be one of the critical issues that an investigator needs to address. Egress models can be utilized to analyze movement of occupants under fire conditions. Integrating egress models with a fire dynamics model is often necessary to evaluate the effect of the fire environment on the occupants. See Section 11.3 on human factors.

21.4.8* Fire Dynamics Analysis. Fire dynamics analyses consist of mathematical equations derived from fundamental scientific principles or from empirical data. They range from simple algebraic equations to computer models incorporating many individual fire dynamics equations. Fire dynamics analysis can be used to predict fire phenomena and characteristics of the environment such as the following:

(1) Time to flashover
(2) Gas temperatures
(3) Gas concentrations (oxygen, carbon monoxide, carbon dioxide, and others)
(4) Smoke concentrations
(5) Flow rates of smoke, gases, and unburned fuel
(6) Temperatures of the walls, ceiling, and floor
(7) Time of activation of smoke detectors, heat detectors, and sprinklers
(8) Effects of opening or closing doors, breakage of windows, or other physical events

21.4.8.1 Fire dynamics analyses can be used to evaluate hypotheses regarding fire origin and fire development. The analyses use building data and fire dynamics principles and data to predict the environment created by the fire under a proposed hypothesis. The results can be compared to physical and eyewitness evidence to support or refute the hypothesis.

21.4.8.2 Building, contents, and fire dynamics data are subject to uncertainties. The effects of these uncertainties should be assessed through a sensitivity analysis and should be incorporated in hypothesis testing. Uncertainties may include the condition of openings (open or closed), the fire load characteristics, HVAC flow rates, and the heat release rate of the fuel packages. See Section 21.6 for recommended data-collection procedures.

21.4.8.3 Fire dynamics analyses can generally be classified into three categories: specialized fire dynamic analyses, zone models, and field models. They are listed in order of increasing complexity and required computational power.

21.4.8.3.1* Specialized Fire Dynamics Routines. Specialized fire dynamics routines are simplified procedures designed to solve a single, narrowly focused question. In many cases, these routines can answer questions related to a fire reconstruction without the use of a fire model. Much less data is typically required for these routines than is required to run a fire model. Examples of fire dynamics routines can be found in NUREG–1805, Fire Dynamics Tools (FDTs).

21.4.8.3.2 Zone Models. Most of the fire growth models that can be run on personal computers are zone models. Zone models usually divide each room into two spaces or zones, an upper zone that contains the hot gases produced by the fire, and a lower zone that is the source of the air for combustion. Zone sizes change during the course of the fire. The upper zone can expand to occupy virtually all the space in the room.